

# Gulfstream-V SVS Integrated Technology Evaluation (GVSITE)

## Demonstration Pre-Flight Brief

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**Synthetic Vision Systems**  
**Project Manager**

**22-23 July 2004**





# Aviation Safety & Security Program



## Aviation Safety & Security Program: Synthetic Vision Systems Project

### Goal:

Decrease the aircraft fatal accident rate and the vulnerability of the air transportation system to threats and mitigate the consequences of accidents and hostile acts

### Objectives:

- **Develop and demonstrate technologies that reduce aircraft accident rates** and reduce aviation injuries and fatalities when accidents do occur
- Develop technologies that reduce the vulnerability of the National Airspace System to terrorist attacks while dramatically improving efficiency of security
- Transfer these advanced concepts, technologies and procedures through a partnership with the Federal Aviation Administration (FAA) and the Transportation Security Administration (TSA) in cooperation with the U.S. aeronautics industry



### Outcomes:

- By 2005, enable a reduction of the aviation fatal accident rate by 50% from the FY 91-96 average.
- By 2009, enable a reduction in the vulnerability exposure of aircraft and other components in the air transportation system.
- By 2012, facilitate the near real-time identification and resolution of risks and vulnerabilities in the air transportation system.



# AvSSP Strategic Foci



**Aviation Safety & Security Program: Synthetic Vision Systems Project**

Aeronautics Research

## Human Error Avoidance



ARC, LaRC

## System Vulnerability Discovery & Management



ARC, GRC, LaRC, DFRC, JPL

Protecting  
Air Travelers  
and the Public

## Hostile Act Intervention & Prevention



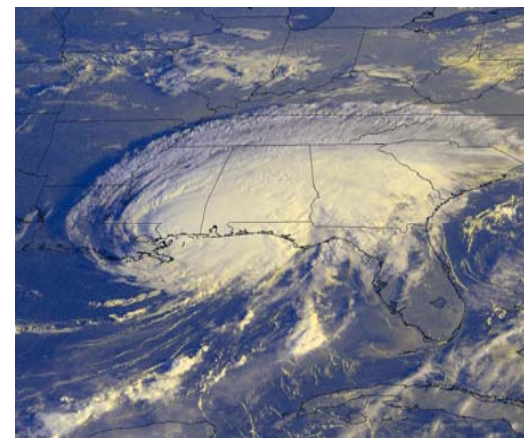
LaRC, GRC, ARC, DFRC

## Aircraft Self-Protection & Preservation



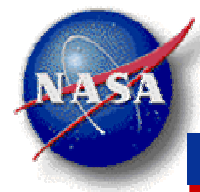
LaRC, GRC

## Environmental Hazards Awareness & Mitigation



LaRC, GRC, DFRC





# SVS Project Goal & Objectives



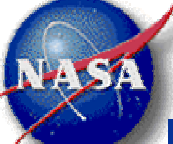
*Aviation Safety & Security Program: Synthetic Vision Systems Project*

- **GOAL**

Eliminate **low-visibility** induced incidents and accidents in support of the National goal to reduce the fatal aircraft accident rate

- **OBJECTIVES**

- **Virtually eliminate CFIT – a leading cause of worldwide commercial jet fatalities**
- Mitigate the number one cause of GA fatal accidents- loss of the horizon for any reason- (low-visibility loss of control & CFIT)
- **Prevent most runway incursions – responsible for the world's deadliest aviation accident**
- Greatly reduce low-visibility induced approach and landing errors

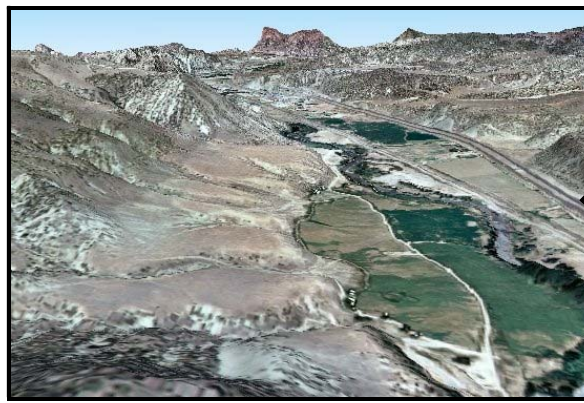


# Synthetic Vision System Definition



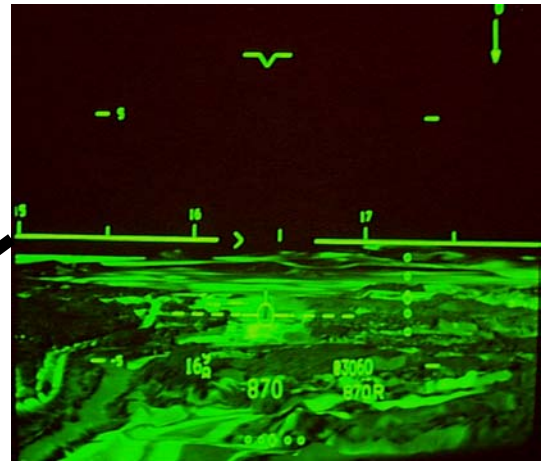
*Aviation Safety & Security Program: Synthetic Vision Systems Project*

A database derived system utilizing precise GPS navigation & integrity-monitoring sensors (as required) to provide a unrestricted synthetic view of the aircraft's current external environment, regardless of weather or time of day



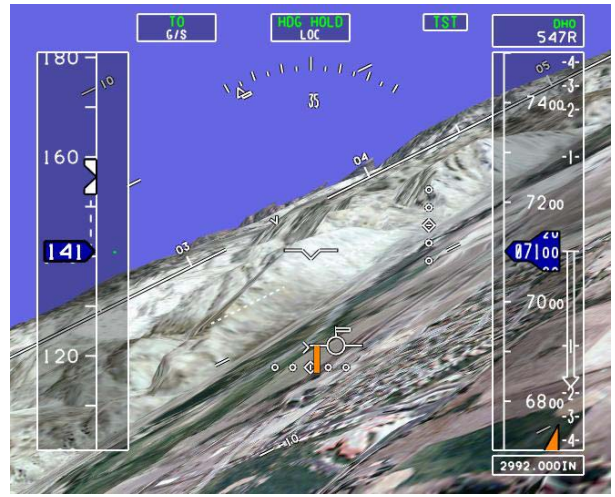
**Worldwide Terrain, Obstacle & Airport Databases**

**IRS / GPS  
(LAAS/ WAAS)**



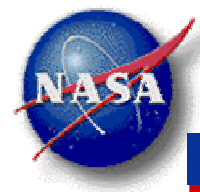
**Advanced Sensors for Database Integrity & Object Detection**

**Real-time tactical hazards (Wx, NOTAMS)**



**Real-time Synthetic Vision Display w/ Advanced Guidance**

**Relevant Traffic Data (TCAS, ADS-B, TIS-B)**



# Synthetic Vision Definition Update



*Aviation Safety & Security Program: Synthetic Vision Systems Project*

January 9, 2004

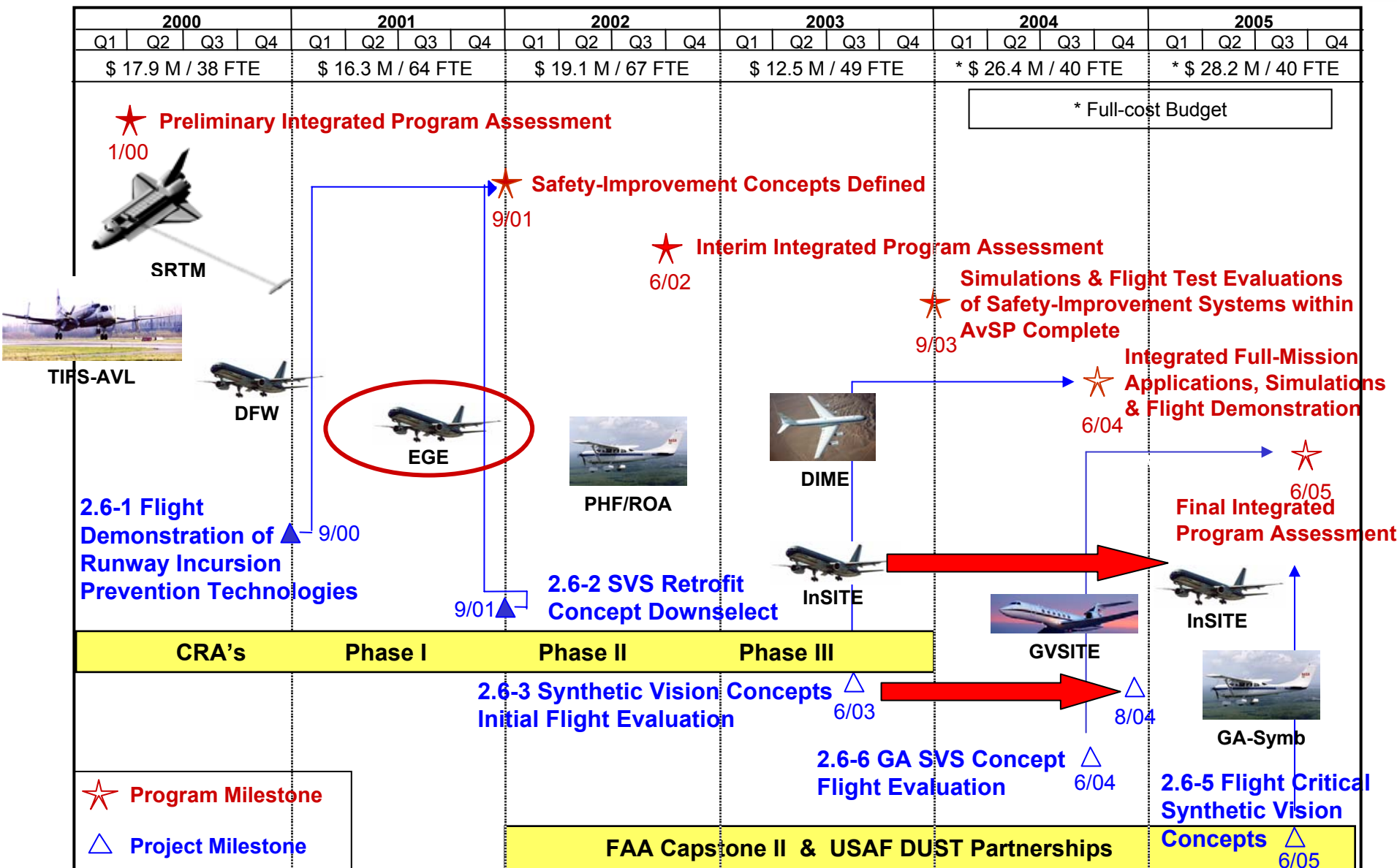
- **FAA Final Rule: Enhanced Flight Vision Systems**
  - 14 CFR Parts 1, 91, 121, 125, and 135 [Docket No. FAA-2003-14449; Amendment Nos. 1-52; 91-281; 121-303; 125- 45; 135-93]
  - The FAA is revising its regulations for landing under instrument flight rules to allow aircraft to operate below certain specified altitudes during instrument approach procedures, even when the airport environment is not visible using natural vision, if the pilot uses certain FAA-certified enhanced flight vision systems. This action informs the public and the aviation industry of the **approval of the use of new technology for certain operational benefits**
- **Synthetic vision** is a **computer-generated** image of the **external scene** topography from the **perspective** of the flight deck that is derived from aircraft attitude, a **high-precision navigation** solution, and a **database** of terrain, obstacles, and relevant cultural features.
- A synthetic vision system is an electronic means used to display a synthetic vision image of the external scene topography to the flight crew.

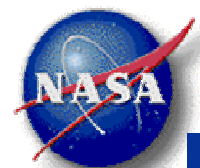


# SVS Technology Development Roadmap



## Aviation Safety & Security Program: Synthetic Vision Systems Project





# SVS EGE Flight Test Video (757)



*Aviation Safety & Security Program: Synthetic Vision Systems Project*



## 106 Approach and Departure Runs

### – 87 NASA Runs

- 52 Visual Arrivals to Runway 07 with KREMM Departures
- 35 FMS25 Arrivals with Cottonwood 2 Departures



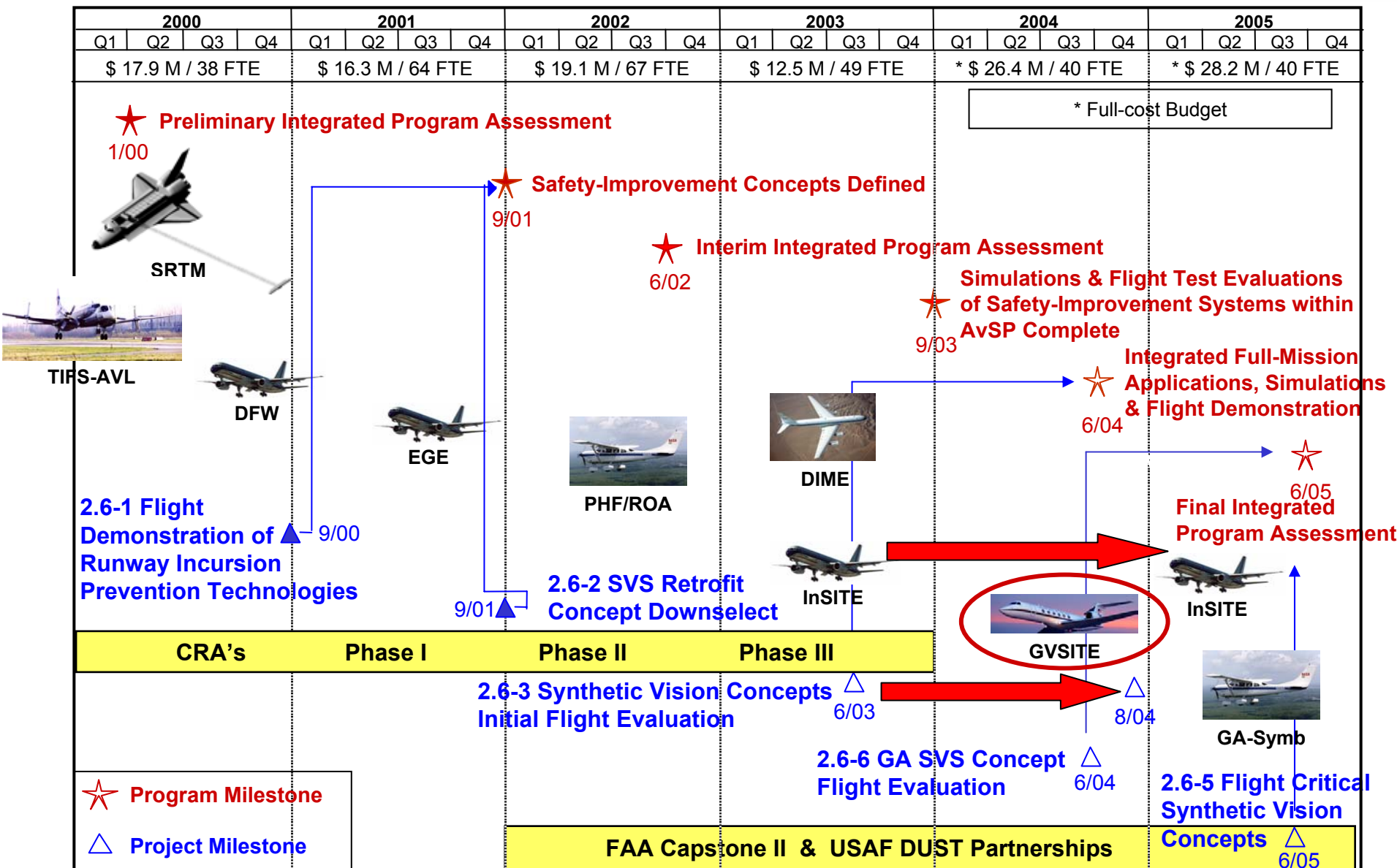




# SVS Technology Development Roadmap



## Aviation Safety & Security Program: Synthetic Vision Systems Project



**CRA's**

**Phase I**

**Phase II**

**Phase III**

**FAA Capstone II & USAF DUST Partnerships**

**FAA Capstone II & USAF DUST Partnerships**

**★ Program Milestone**

**△ Project Milestone**





# Things in the Database are ***RIGHT***



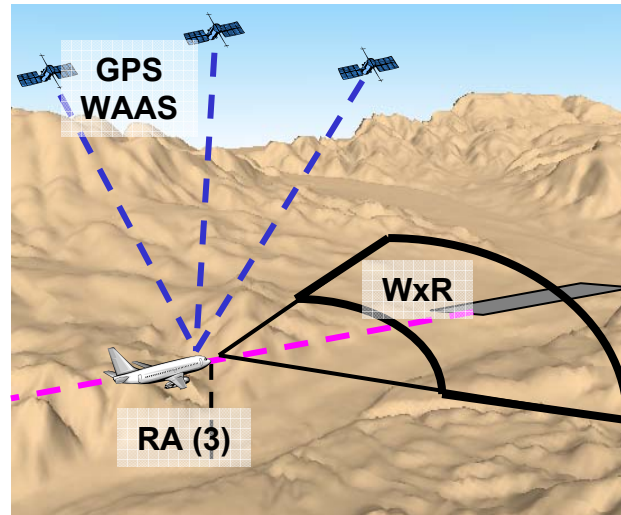
**Aviation Safety & Security Program: Synthetic Vision Systems Project**

## Database and System Integrity

(Source Data and Data Processing Integrity Addressed Separately)

### Ensure the Database is Correct

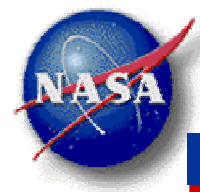
- Integrity Layers to ensure Trustworthy data
  - Quality Source Data (Jepp)
  - Certified Life-Cycle Processes (Jeppesen)
  - Real-Time Monitoring (NASA, Ohio University)
    - Radar Altimeter
    - Wx Radar
      - Runway Outline
      - Terrain Feature Extraction
    - GPS Bi-Static Radar



**Database  
Integrity  
Monitoring  
Equipment  
(DIME)**



- Terrain Feature Extraction
- Runway Outline



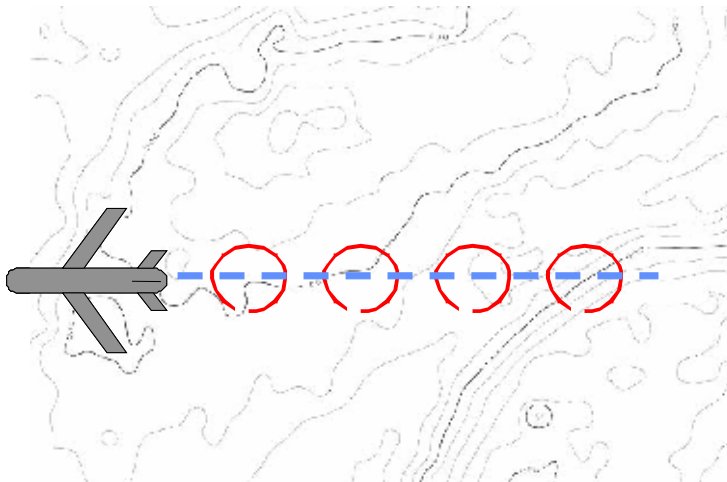
# Real-time Database Monitoring



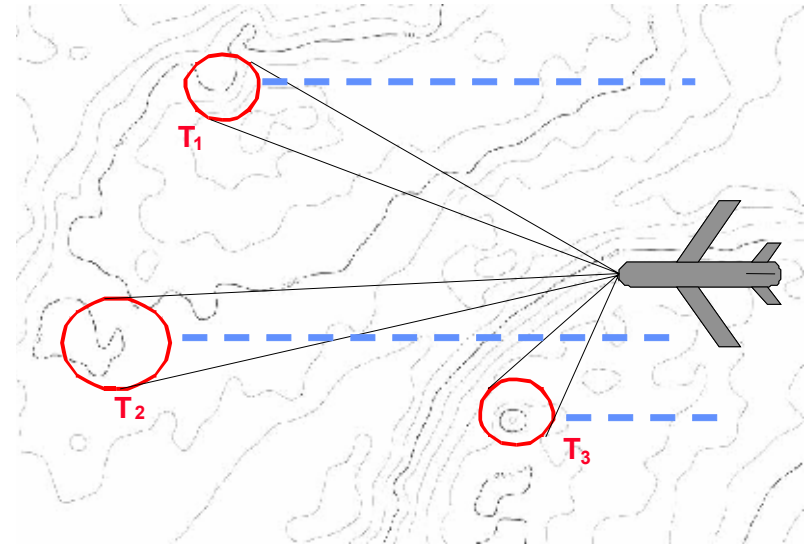
*Aviation Safety & Security Program: Synthetic Vision Systems Project*

**Operational concept: compare sensed with stored data...**

**...when 'significant' differences occur, inform the pilot**



Down-looking sensor to detect errors primarily in the vertical  
[UdH, 5-01], [Gra, 6-99]



Fwd-looking sensor to detect errors both in the vertical & horizontal, and provide more "timely warnings..."

Fwd-looking lateral coverage should help detect errors while turning in flight

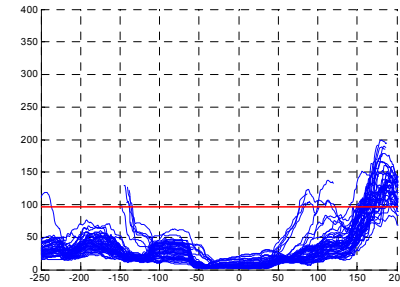
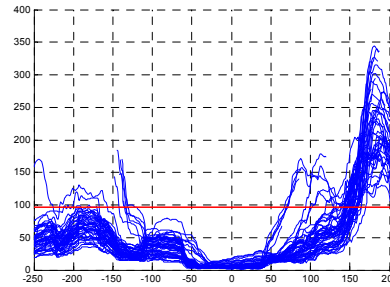
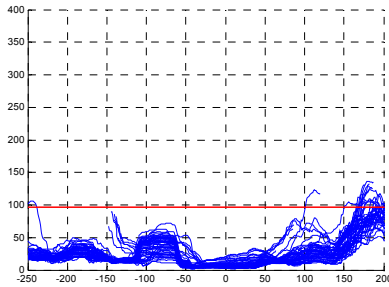
Fwd-looking sensor may reduce minimum detectable errors





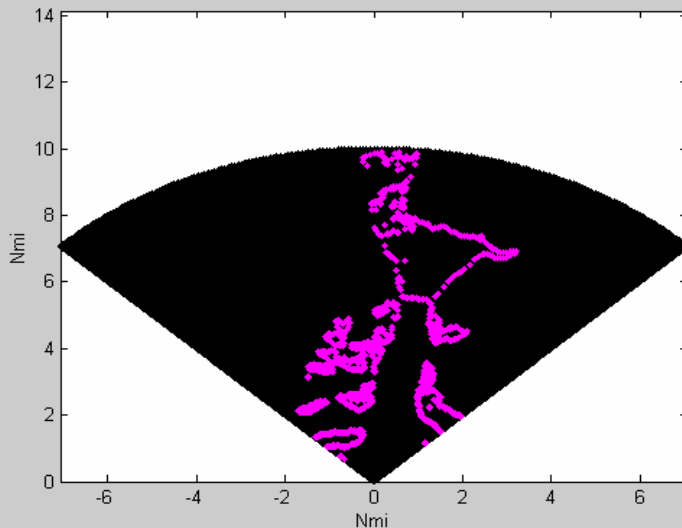
# Database Integrity Monitoring Equip.

*Aviation Safety & Security Program: Synthetic Vision Systems Project*

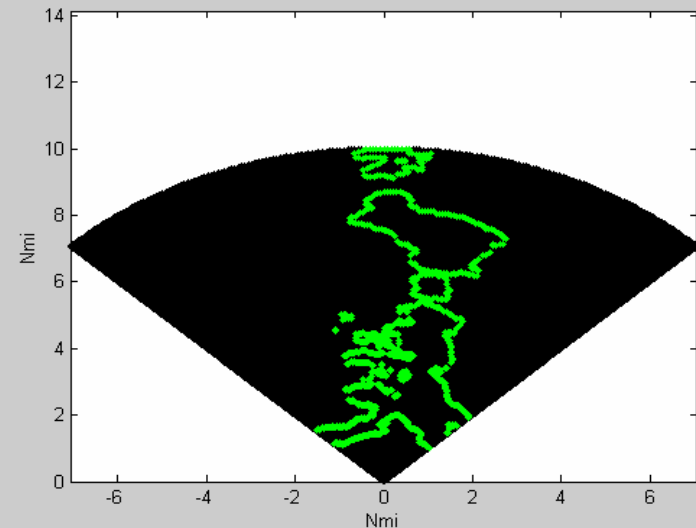


## Ranging sensors compared to calculated altitude above terrain database or calculated DEM RADAR shadow zones

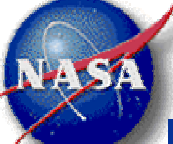
- Flight tests utilizing the DFRC DC-8 and an Airborne Laser Terrain Mapper (ALTM) were used to determine correct error model for radar altimeters & for terrain features extracted from Wx radar



**DEM-derived Features**



**Radar-derived Features**



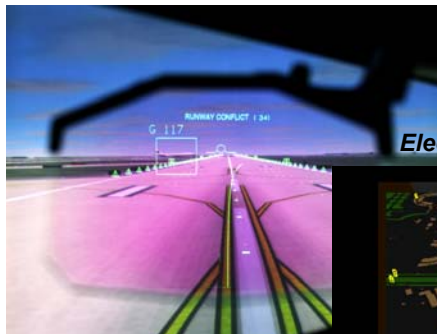
# Things Not in the Database are *Represented*



## Aviation Safety & Security Program: Synthetic Vision Systems Project

- Integration of RIPS & SVS

Runway Incursion Prevention System (RIPS))



Electronic Moving Map (EMM)



SVS-HUD Concept

- Obstacle Detection



### Things not in the Database are Represented

- NOTAMs

- Unmapped Obstacles (e.g., Towers)
- Closed Runways / Taxiways

- Surveillance

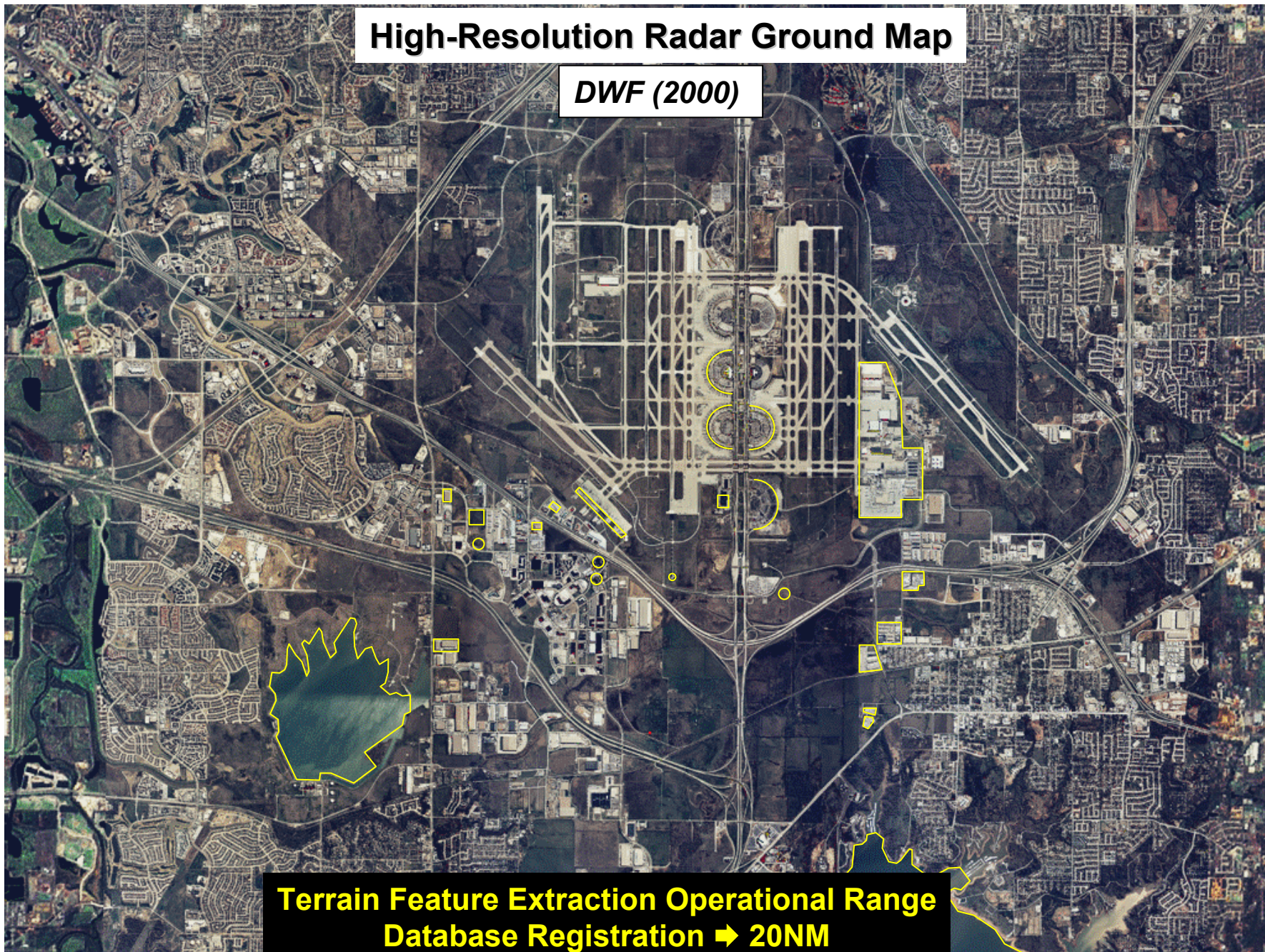
- ADS-B / TCAS CDTI
- ADS-B / TIS-B Ground CDTI
- Onboard Runway Incursion Prevention System
- Air-to-Ground Weather Radar Object Detection (e.g., Obstacles on Runway, Obstacles to Flight)
- Grnd-to-Grnd Weather Radar Object Detection (e.g., Obstacles on Runway / Taxiway)



# High-Resolution Radar Ground Map

*DWF (2000)*

**Terrain Feature Extraction Operational Range  
Database Registration ➔ 20NM**





# DFW-2000 & EGE-2001 Tech Transfer

As a result of NASA flight test data and research results Collins has launched Runway Object Detection as new commercial radar application in its WXR-2100 Wx-Radar product



Radar Control & Real-Time Processing/Recording System



First Ever Recordings Using NASA EVS Mode  
(Rep. 5-10 yr Adv. Industry Product Line)



Modified Commercial  
WX Radar Transceiver  
(Sig. Adv. in Transceiver Design)



Modified Commercial  
WX Radar Antenna  
(Sig. Adv. in Antenna Design)





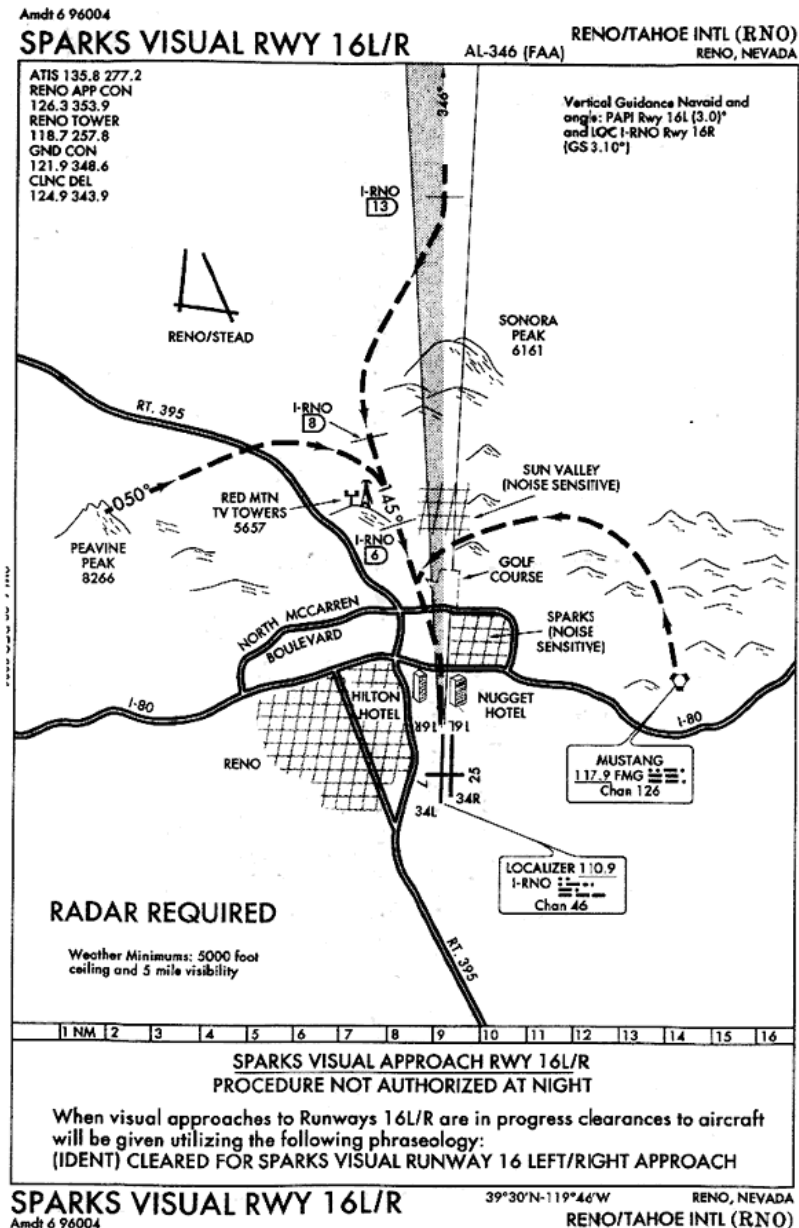


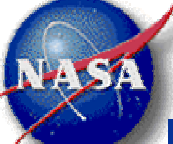
# GVSITE Flight Test



## Aviation Safety & Security Program: Synthetic Vision Systems Project

- Investigate visual arrivals performed in simulated IMC conditions utilizing SVS technology
- “Virtual VMC” possible with SVS
  - Potential reduction of high ceiling and visibility minimums
  - Night operations possible
  - Ease Radar requirement
  - Enable complex noise-abatement approaches for any runway
- Complementary Testing Objectives
  - RNO - Emphasis on Database Integrity Monitoring Equipment
  - WAL - Emphasis on Runway Incursion Prevention System
  - Remaining Objectives Spread Across Locations





# GVSITE Partners



*Aviation Safety & Security Program: Synthetic Vision Systems Project*

**SVS-CaB CRA Partner**

**Rockwell  
Collins**

**RIPS CRA Partner**

Rannoch

**PATHPro**

Synthetic Vision Information Systems (SVIS)

**Database CRA Partner**



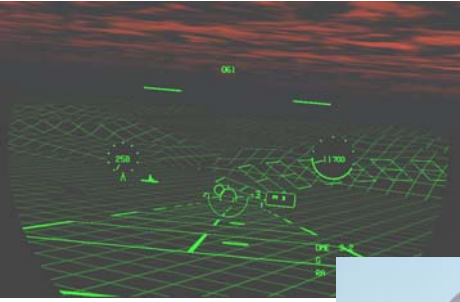
**DIME CRA Partner**



**DUS&T Partner**



**Gulfstream**  
A GENERAL DYNAMICS COMPANY



AFRL







# Flight Test Equipment Installation

*Aviation Safety & Security Program: Synthetic Vision Systems Project*



## Gulfstream G-V Ship 501



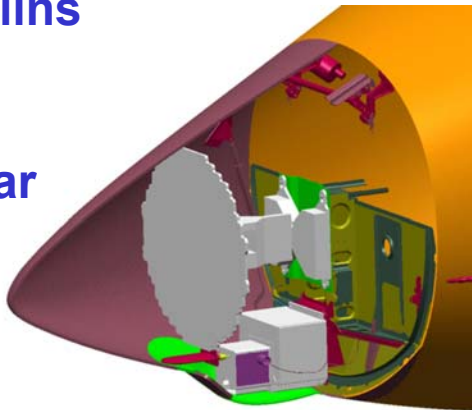
Flight  
Dynamics  
HUD  
Installation

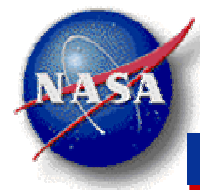
Voice  
Recognition  
System

Rockwell-Collins 8"x8" LCD Displays



Rockwell-Collins  
WxR – 2100  
Modified  
Weather Radar





# RNO Airport Model Details



*Aviation Safety & Security Program: Synthetic Vision Systems Project*

## Features

- **RTCA DO-272 compliant**
- 28 entity types
- RIPS runway/taxiway routing connectivity

## Source

- Ground survey by **Jeppesen/Darmstadt University**
- Other features digitized by **Jeppesen** from QuickBird2 0.7m imagery
- Regional obstacles obtained from the FAA/NACO Digital Obstruction File

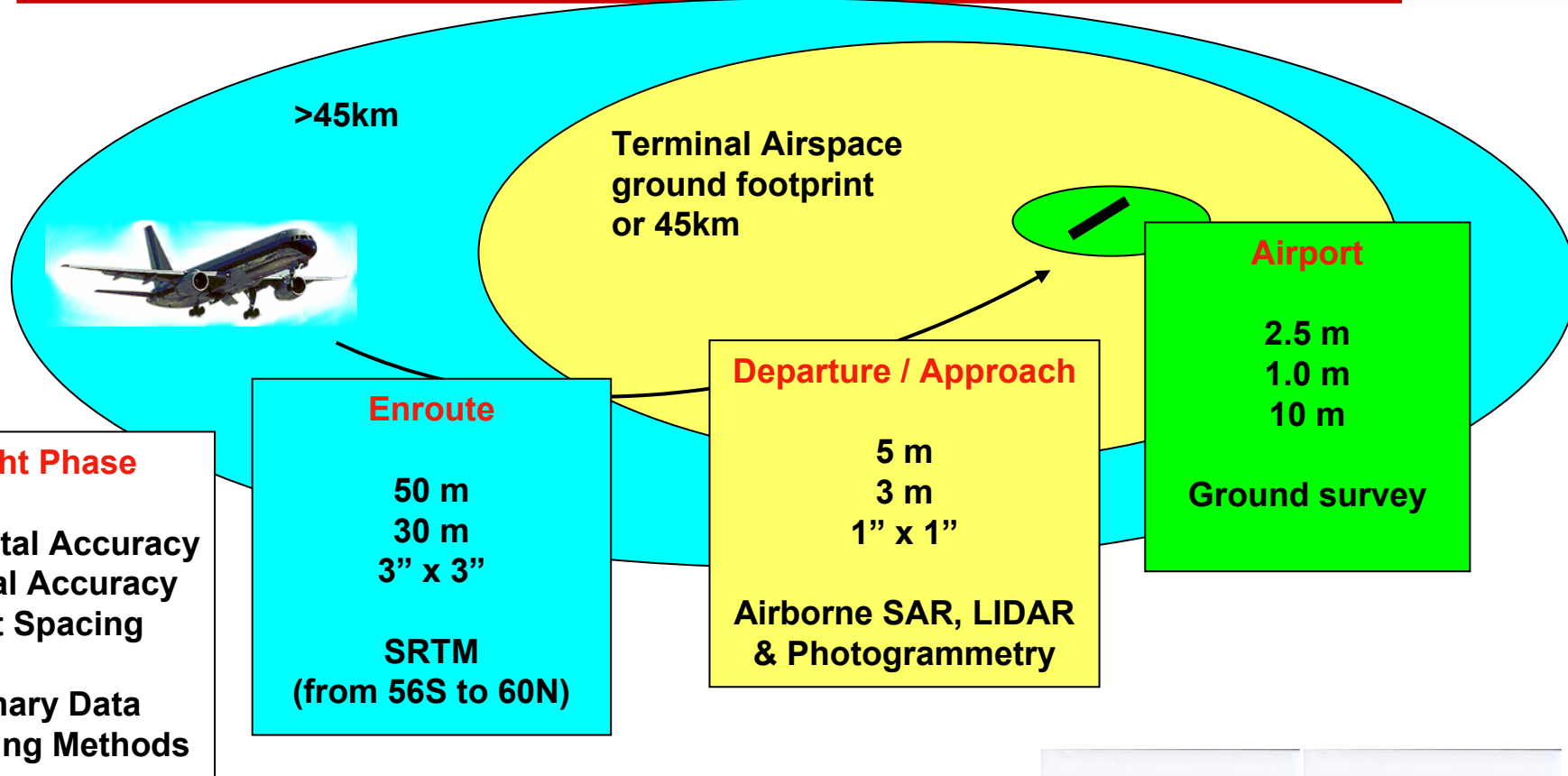






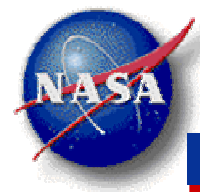
# RTCA Database Standards Confirmation

Aviation Safety & Security Program: Synthetic Vision Systems Project



NASA leadership on international committees helped to develop the first **international standards for aviation database applications**: RTCA DO-272 & DO-276

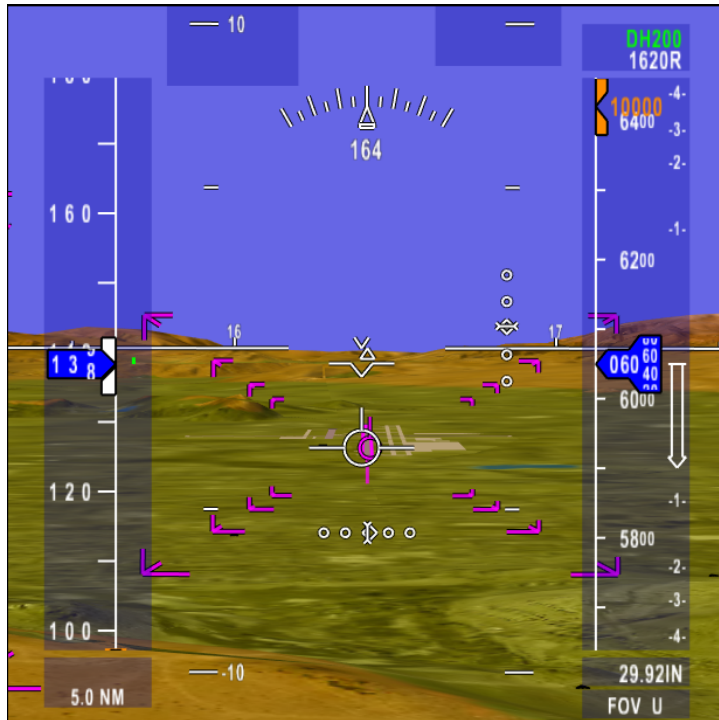




# Hybrid Texturing



*Aviation Safety & Security Program: Synthetic Vision Systems Project*



- Hybrid Concept:

- Elevation-Based Color Coding
  - False-Coloration of Aerial Photo
- Absolute Not Relative Altitude
- False-Colored Bodies of Water

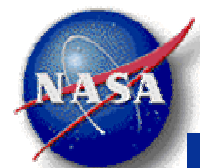


- Database

- USGS NED 1 ArcSec (30 m Post-Spacing) Digital Elevation Model
- 1 to 4 m/pixel Nested Aerial Photographic Data



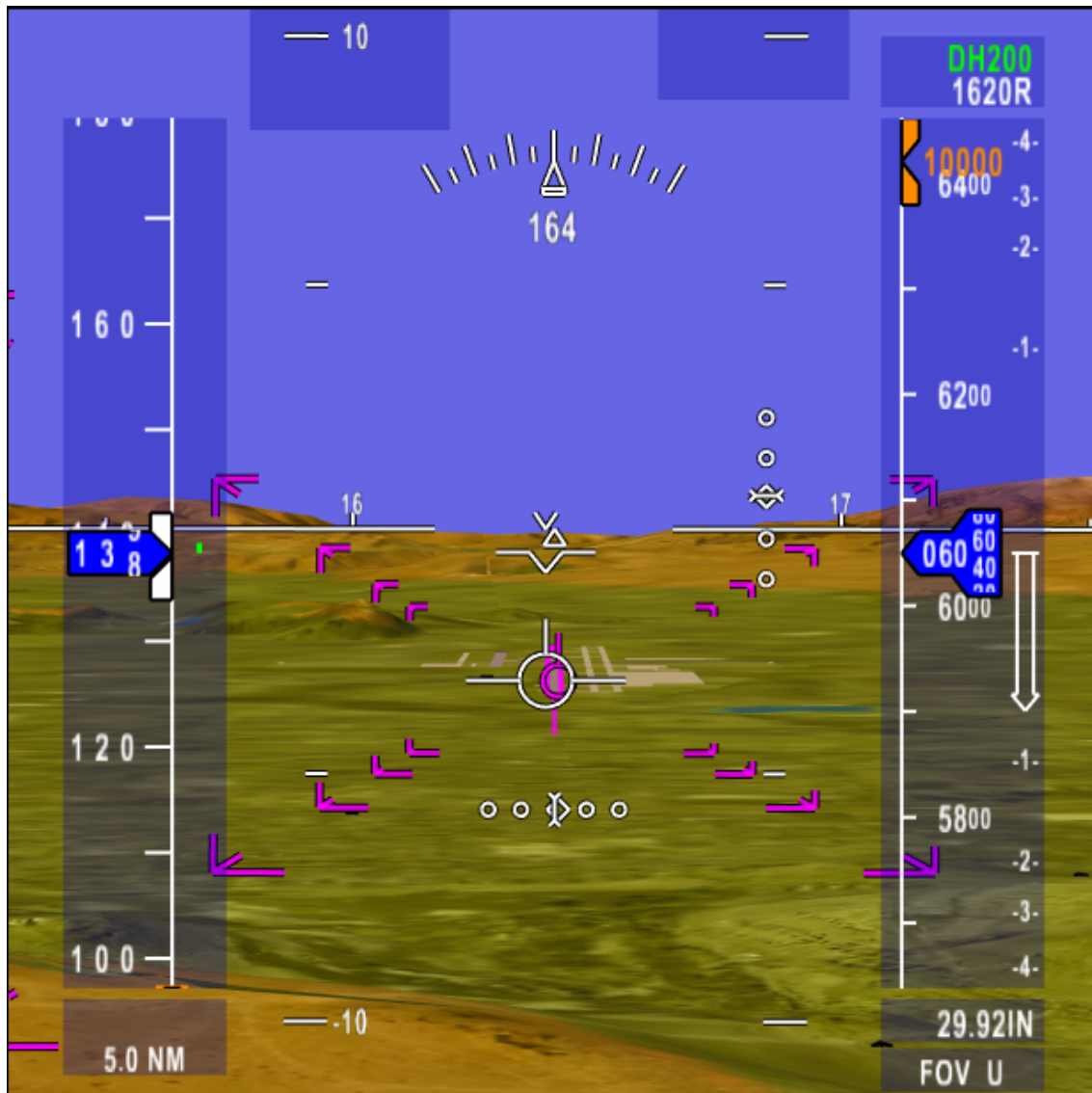
# **Display Concepts / Cockpit Features / Technologies**



# Dynamic Tunnel Concept (1)

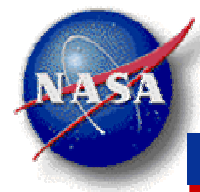


*Aviation Safety & Security Program: Synthetic Vision Systems Project*



- Dynamic Tunnel Concept Objectives:
  - 1) Minimize Display Clutter When on Path
  - Limited Tunnel Definition
  - Limited Path Extent



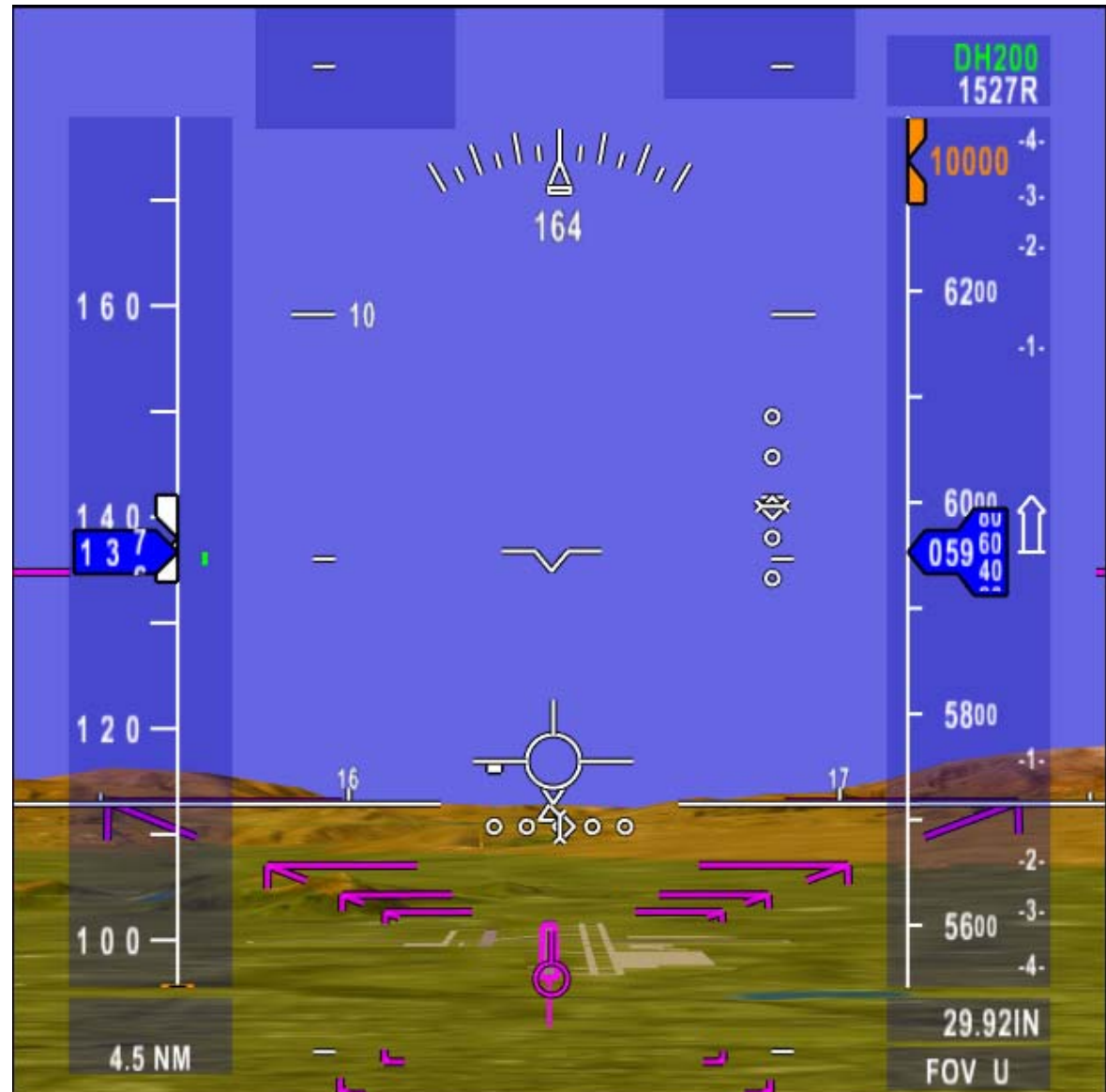


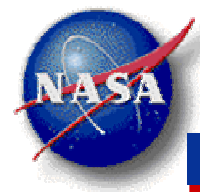
# Dynamic Tunnel Concept (2)



*Aviation Safety & Security Program: Synthetic Vision Systems Project*

- Dynamic Tunnel Concept Objectives:
  - 2) Alert Pilot (Dynamically) To Path Error Within Tunnel
  - More Definitely Outline Tunnel In Direction of Path Error



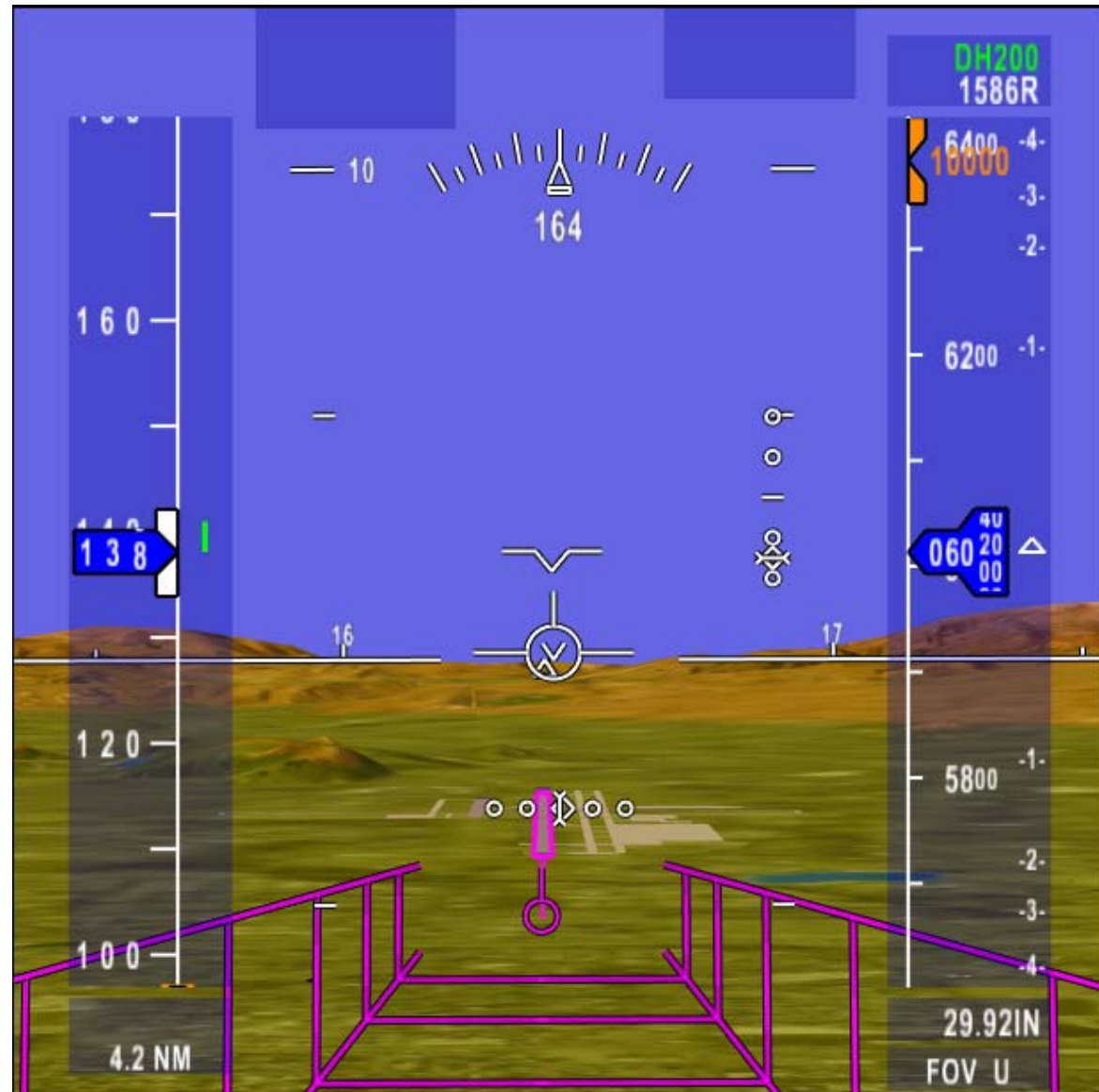


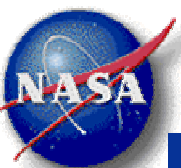
# Dynamic Tunnel Concept (3)



*Aviation Safety & Security Program: Synthetic Vision Systems Project*

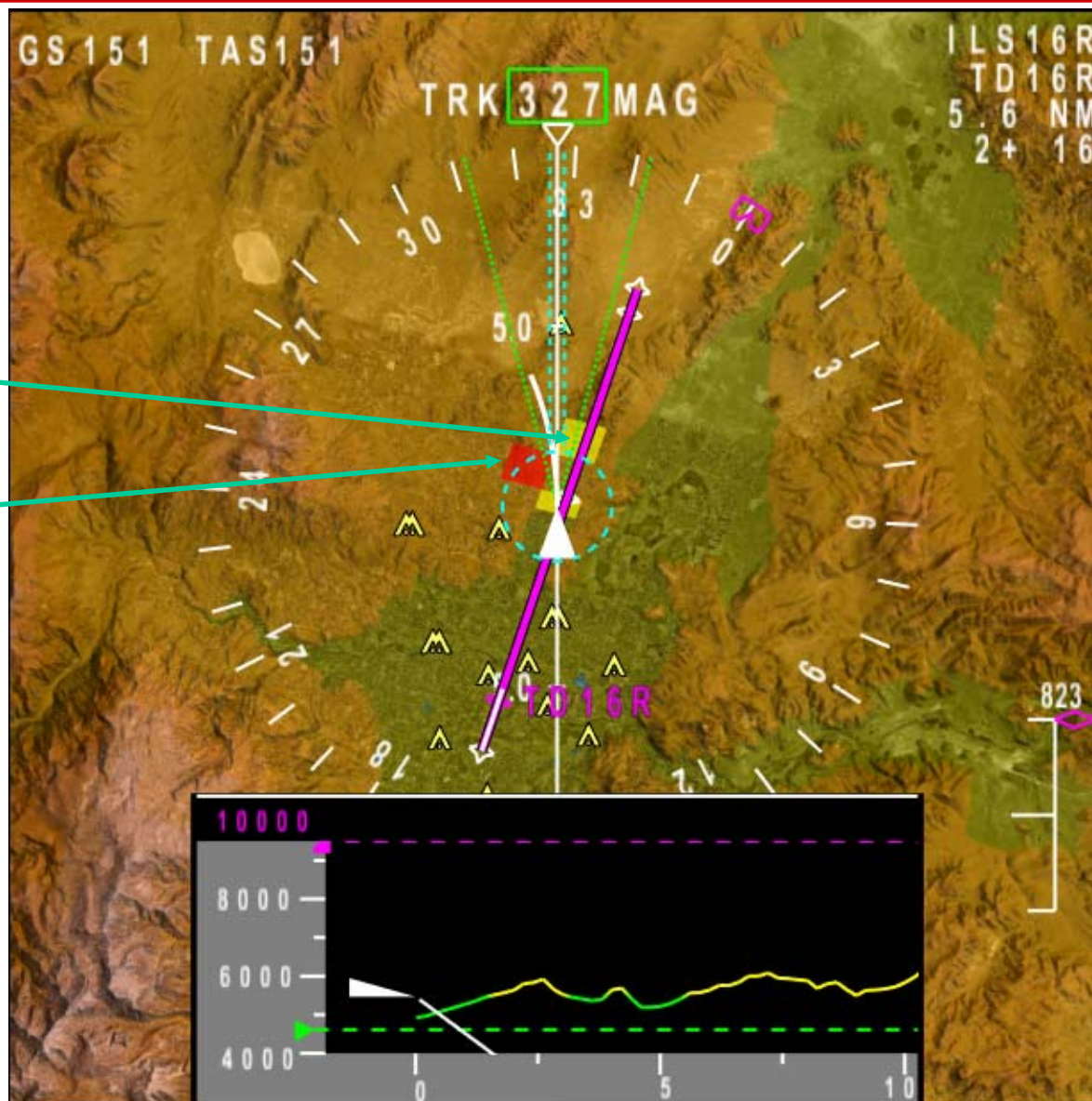
- Dynamic Tunnel Concept Objectives:
  - 3) Unambiguous Alerting of Tunnel Exceedance;
  - 4) Prominent Cues to Recapture Tunnel Path





# Warnings and Cautions Overlay

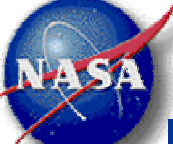
Aviation Safety & Security Program: Synthetic Vision Systems Project



TAWS Caution Alert

TAWS Warning Alert

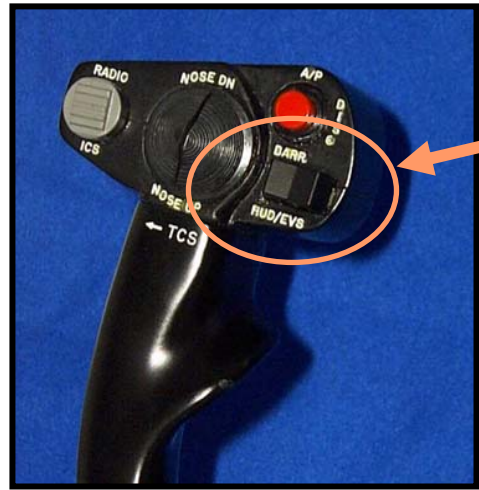




# Voice Recognition System (VRS)



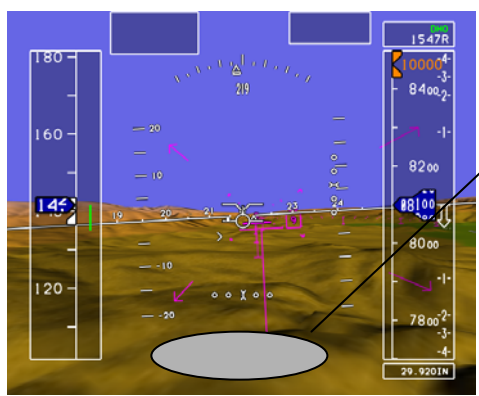
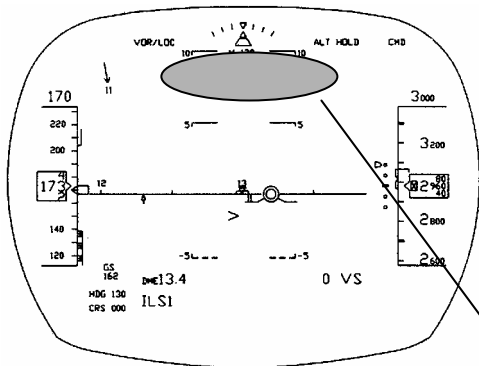
Aviation Safety & Security Program: Synthetic Vision Systems Project



**VRS Push-to-Listen Switch**  
(HUD Declutter Function)

- Speaker Independent
- Commercial Off-the-Shelf

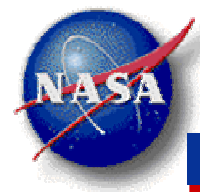
## Message Boxes



## 3 Possible VRS Outcomes

<u>ACTION</u>	<u>MESSAGE</u>
Push Button Depressed	+++++
Command Processed (Recognized Or Misrecognized)	PFD TUNNEL ON
Command Not Recognized	-----

*Correct Recognition*  
*Incorrect Recognition*  
*No Recognition*

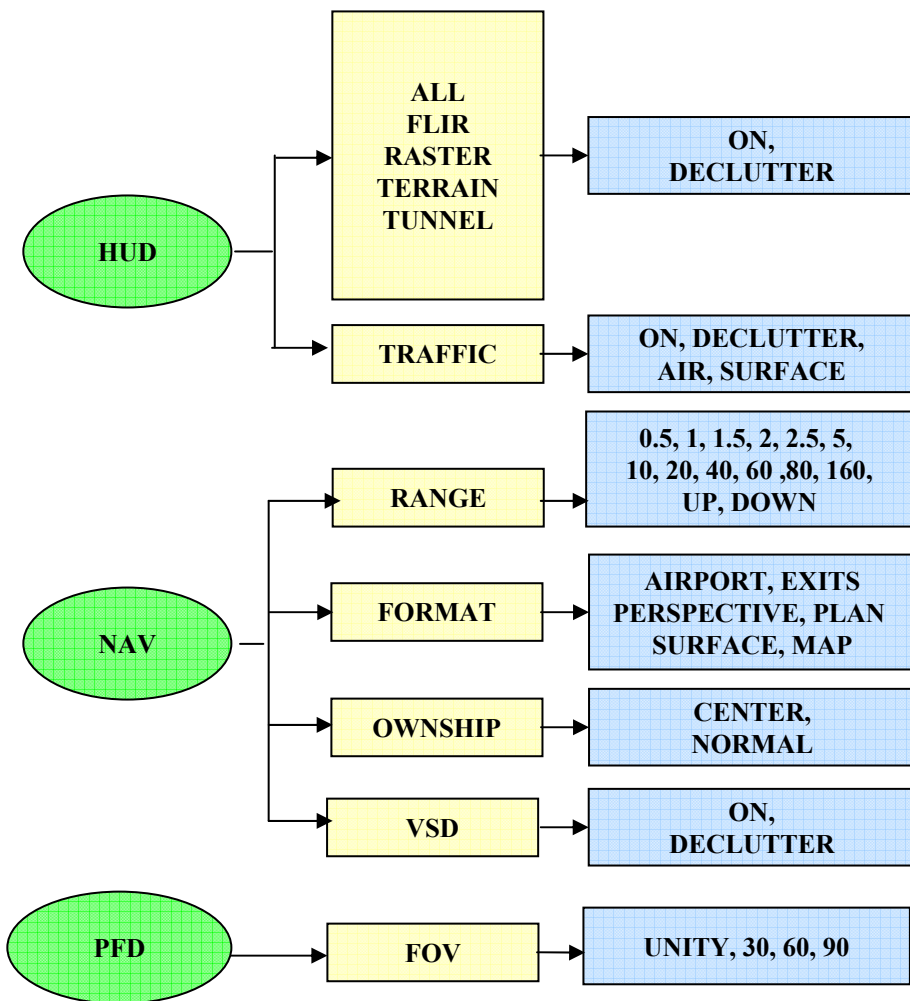


# VRS Vocabulary



**Aviation Safety & Security Program: Synthetic Vision Systems Project**

**Display** ➔ **Display Element** ➔ **Modifier / Adjective**



**Structured Speech Recognition System**  
(As Opposed to Natural Language System)

- *Increased Recognition Rates*
- *Minimal Training Penalty For Aviation Application*

## Global Commands

**CANCEL**

Undoes last command only

**REPEAT**

Repeats last command



# Runway Incursion Prevention System



Aviation Safety & Security Program: Synthetic Vision Systems Project

## Multi-staged Airborne Incursion Prevention Strategy

### II. Know where others are

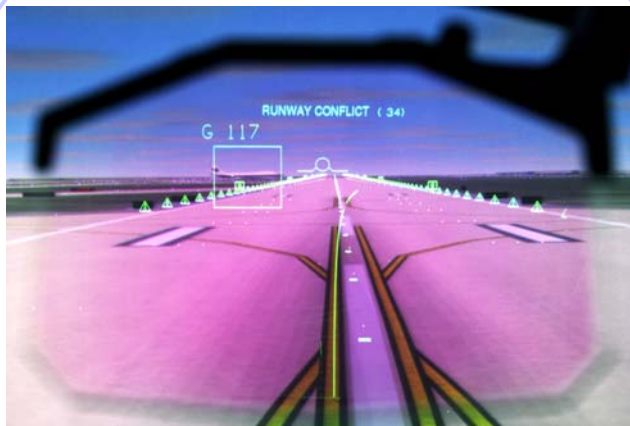
Traffic position awareness  
(ADS-B or TIS-B data link)



Departure Surface Map

### I. Know where you are

Own-ship position awareness  
(GPS & airport database)



HUD Guidance



**"Runway Conflict"**  
**"Runway Traffic"**  
**"Crossing Hold"**  
**"Off Route"**

### III. Know where to go

Route awareness  
(Taxi route from ATC)

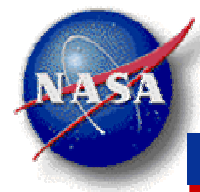


Taxi Surface Map

### IV. Know when a mistake occurs

Incursion detection  
(Immediately alert flight crew & ATC)





# Incursion Alerting Methods



## Aviation Safety & Security Program: Synthetic Vision Systems Project

- Two *Aircraft-based* Alerting Algorithms / Methods Being Tested
  - Rannoch Corp:  
Runway Incursion Advisory and Alerting System (RIAAS)
  - NASA LaRC In-House:  
Runway Safety Monitor (RSM)
- Runway Traffic Alert (RTA) – Cautionary
  - Pilot action not required
  - *Part of Rannoch RIAAS only*
- Runway Conflict Alert (RCA) – Warning
  - Avoidance maneuver required
  - *Provided for both alerting methods*
- Both Algorithms Active for Data Analysis
  - One source chosen for display in cockpit

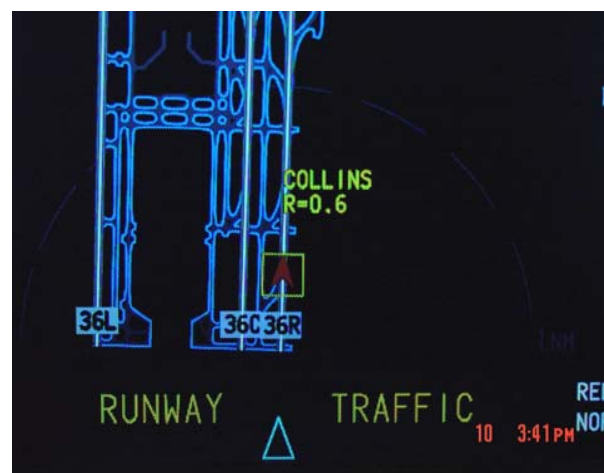


# Cooperative Research Partner- Rannoch



## Aviation Safety & Security Program: Synthetic Vision Systems Project

- Developed set of aircraft-based incursion detection algorithms that provide two-stage alerting to the pilot: Runway Incursion Advisory and Alerting System (RIAAS)
- RIAAS evaluated during:
  - NASA DFW flight test – October 2000
  - NASA simulator test – March 2002
  - Rannoch RIAAS simulator tests
  - Current GVSITE flight test – July 2004
- RIASS safety benefits analysis conducted- significant safety improvements proven
- **RIASS integrated with Rockwell Collins Traffic Surveillance System** and demonstrated in Rockwell Collins flight simulator – March 2003



- **Phase II SBIR awarded to adapt RIAAS for general aviation operations**



# RIPS Scenarios – Crossing Runways

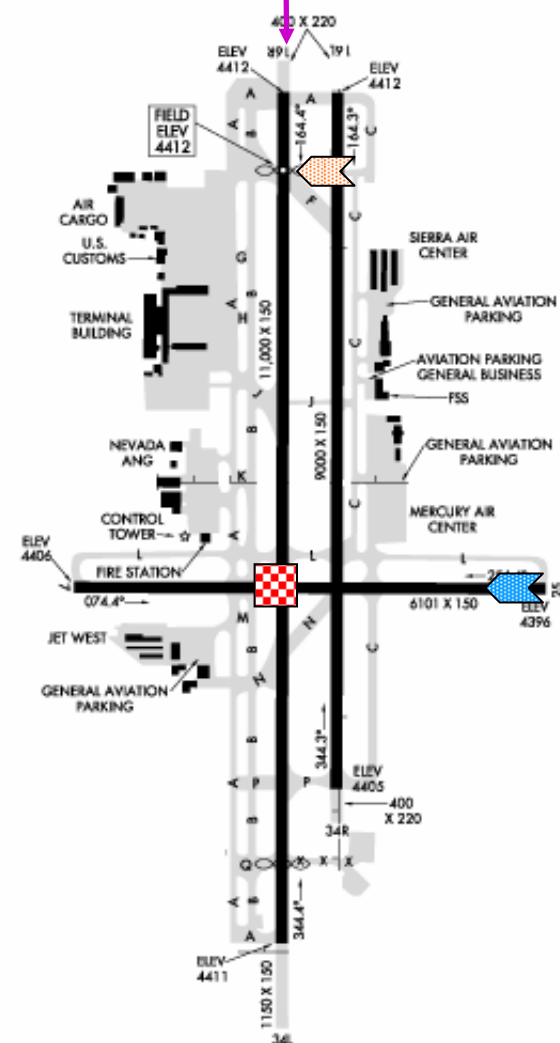


Aviation Safety & Security Program: Synthetic Vision Systems Project

Departure / Departure



Arrival /  
Departure



-  Ownship
-  Traffic (Be200)
-  Traffic (SV-RV)
-  Conflict location





# RIPS Scenarios – Crossing Runways

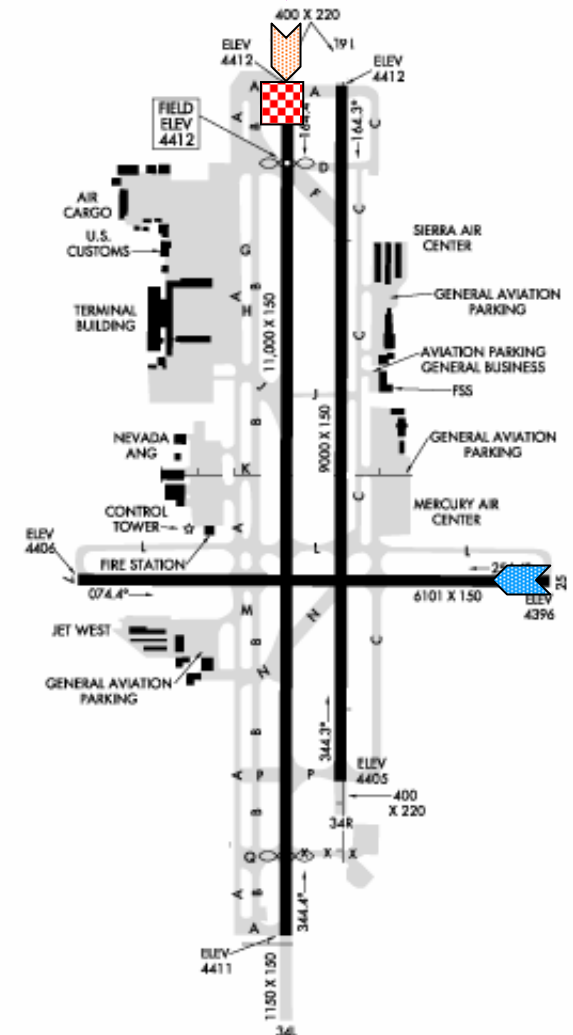
Aviation Safety & Security Program: Synthetic Vision Systems Project



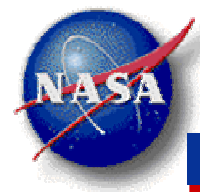
## Taxi Crossing



## Arrival Traffic



-  Ownship
-  Traffic (Be200)
-  Traffic (SV-RV)
-  Conflict location

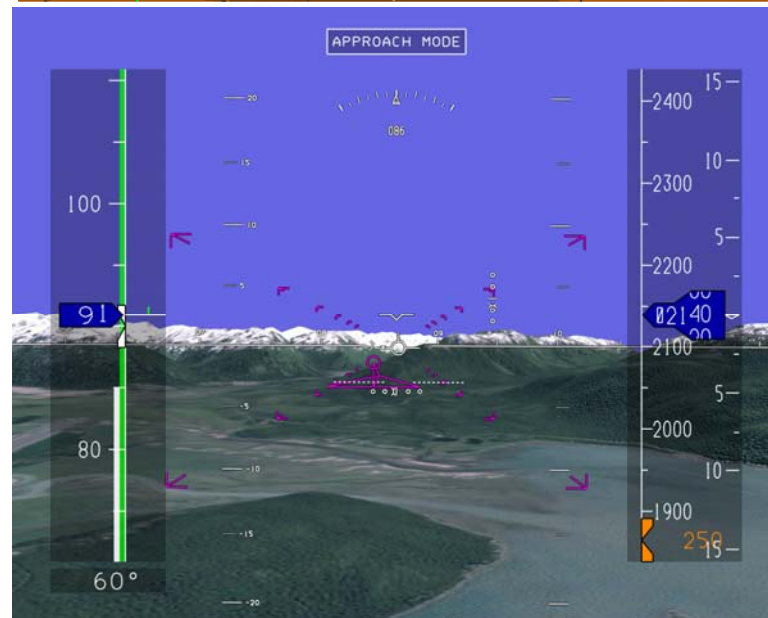
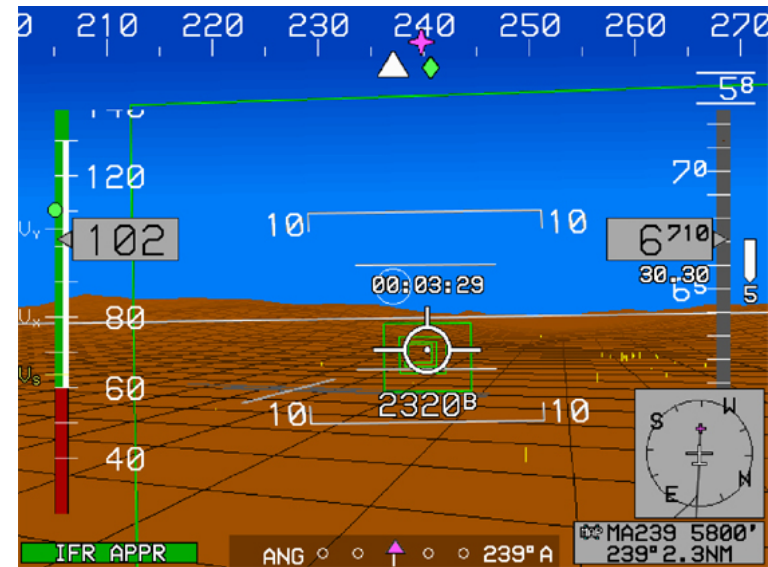


# Synthetic Vision Systems Summary



## Aviation Safety & Security Program: Synthetic Vision Systems Project

- **Synthetic Vision Systems are Emerging**
  - The first SVS (Chelton Flight Systems) has been certified by the FAA, and is commercially available for GA aircraft
- **Numerous Simulation and Flight studies have established the following:**
  - SVS Increases total situation awareness
  - SVS Increases ability to detect & avoid CFIT
  - SVS Reduces flight technical error
  - SVS Reduces pilot workload
- **NASA SVS Project has successfully Partnered w/ the USAF, FAA & Industry to:**
  - Leverage NASA resources
  - Expedite SVS technology development
  - Lead to SVS product implementation
- **Enjoy your flight, we look forward to your comments**



...why does flying have to be so dependent  
on the eyesight of a pilot?...

...what I really need is a pair of  
spectacles to see through the fog...

...Aviation will never amount to much  
until we learn to free ourselves from the mists...



**Charles Lindbergh**



**Charles A. Lindbergh - The Spirit of St. Louis**  
**Charles Scribner's Sons, 1953**





- Enhanced Vision
  - Sensor based
  - May include image processing or even complete reconstruction
- Synthetic Vision
  - Visualization of elements from a computer generated database
  - Could include TCAS, ADS-B and weather data
  - Visualization of path, terrain, traffic and weather
- Fusion
  - Combination of sensor and database elements into one image
- Integration
  - Combination of sensor and database where they are distinguishable

**Synthetic Vision is more than a safety system. It is an integrated flight deck visualization solution. Includes guidance elements to provide real operational benefits.**



# Programs Review

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- SVIS – 5 year, 3 phase program with NASA Langley. Flight testing at DFW, EGE and RNO.
- TAPGuide – 2 year program with AFRL. Flight testing at Edwards AFB on Speckled Trout.
- SGS - Internal development with testing on the BBJ.
- BTD – Technology demonstrations with a Boeing on a 737-900.
- SE-VISION – 2 year program with AFRL and NASA Langley.
- SOES – 2 year program with AFRL and NASA Langley.



# Flight Deck Visualization Needs

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- Make Every Flight the Equivalent of Clear-Day Operations
  - A Complete Vision of the Outside World, in All Wx & Conditions
  - Reduce Spatial Disorientation contributing factors
- The Ability to Conduct Preferred/Standardized Ops in Any Terrain/Wx Condition - Critical to Both DoD & Commercial
  - “Own the Weather” “Free-Flight”
- View Entire Battlefield with Identification of Threats, Targets, and Friendlies from the Vehicle Perspective
- Efficiency Improvements in “Gate to Gate” Ops by Combining Terrain, Traffic, Wx, path guidance & Surface Ops Information
- Simplified Aircraft Systems Management (Integrate and Monitor/Control Through Graphical User Interface)
- Reduce Crew Training Costs

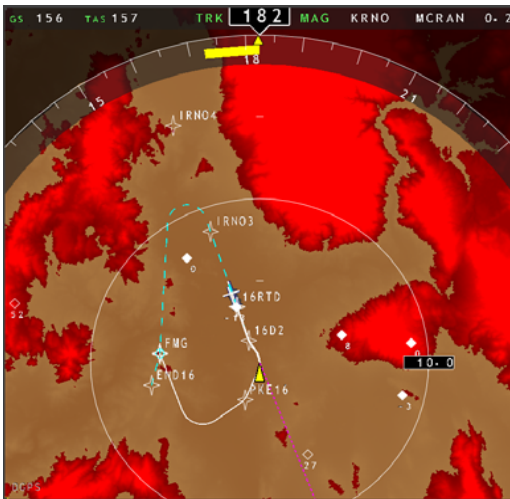
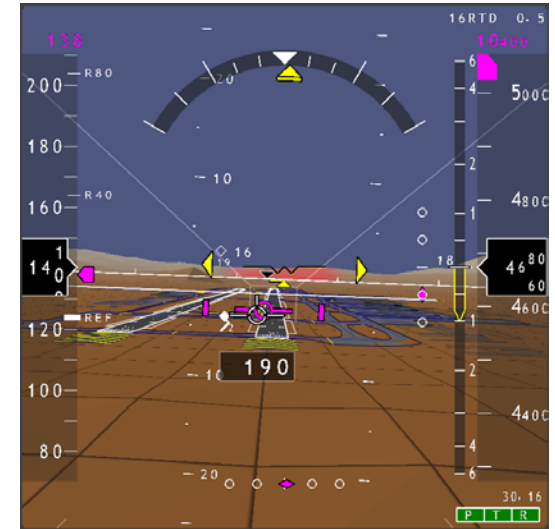
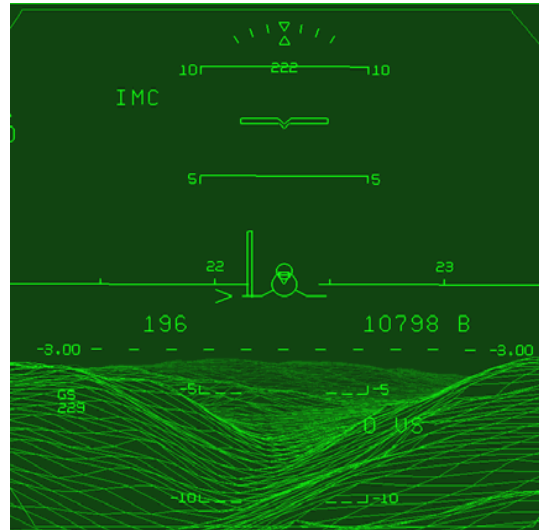




- What is Synthetic Vision and Perspective displays
  - Surface and pathway displays are synthetic vision
- Small simple databases and small simple textures
  - Avionics architectures require innovative solutions
- Photo-realistic not required or desirable
  - HF studies show no performance improvement and reduced recognition time due to clutter
  - Only helps for complete environment familiarity
- Guidance concept is vitally important
  - True operational benefit is in the guidance, visualization gives equivalent or higher levels of safety
- Certification
  - Path for local procedures
  - Investigate integrity monitoring



# RC SVIS Displays





# SE-VISION

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- Rockwell Team
- Flight test
  - Flight test as part of NASA SVIS program
    - GV aircraft
    - Wideband FLIR
    - Modified WXR-2100
    - Database integrity monitoring function
    - HUD, HDD for approach and taxi
  - Flight test on FAA 727
    - Display format candidates based on HF study
    - Military and Transport pilots
    - Dual band FLIR, MMw and image fusion processor
    - Modified WXR-2100
    - Flight test in early FY06









- We have the Opportunity to Define New Operational Paradigm for Aviation with Increased Safety, Efficiency & Effectiveness for Military and Commercial tasks
- Demonstrations on 757, BBJ, 737, C-135 and GV
- Technology demonstrated for commercial and military operations in terrain challenged environments
- Guidance for manual and automatic flight

We have the opportunity to change how airplanes are flown and create major economic benefits for our customers –  
**We** can turn Lindbergh's dream into reality





# The Team at Work



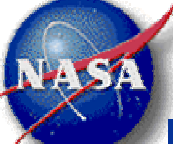


# Contact Information

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# Logistics: G-V Layout for GVSITE

*Aviation Safety & Security Program: Synthetic Vision Systems Project*

